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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

PROPULSION EXPERIMENTS WITH A TUNNEL HULL PLANING CRAFT TO DETERMINE OPTIMUM LONGITUDINAL PLACEMENT OF PROPELLERS AND EFFECTS OF NOZZLE SIDEPLATES IN THE TUNNELS

BY

GARY BORDA

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SHIP PERFORMANCE DEPARTMENT REPORT

APRIL 1982

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DTNSRDC/SPD-0717-02

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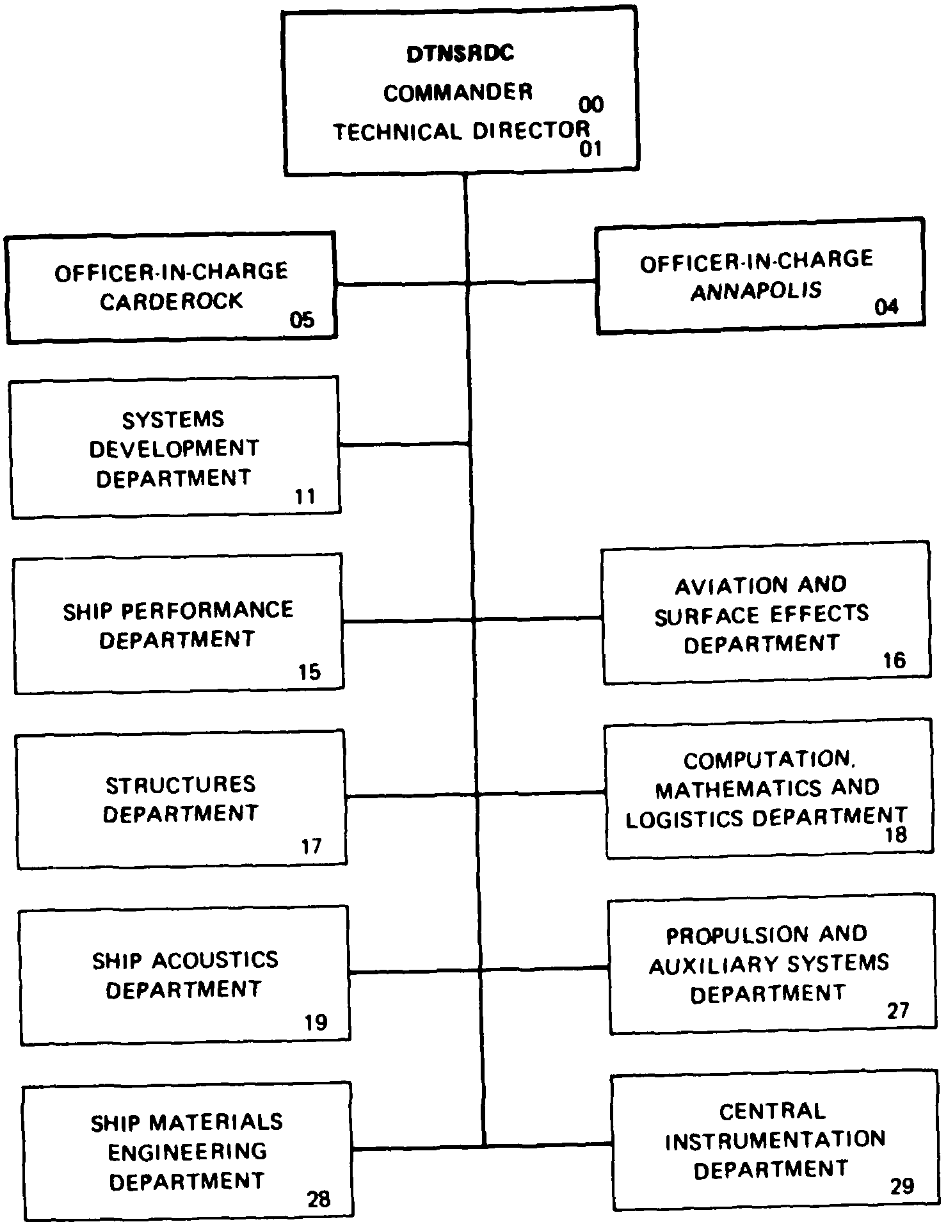

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This report consists of an experimental evaluation of tunnel hull configurations on a planing hull model and determination of the optimum longitudinal placement of the propeller in an existing tunnel design. Resistance, self-propulsion, and draft data are presented for Model 5048 fitted with twin tunnels which have a depth of 40 percent of the tunnel diameter. Effects of propeller tip clearance and nozzle sideplates installed in the tunnels were also investigated.

(Block 20 Continued)

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NOTATION

The notation contained herein conforms with I.T.T.C. notation as presented in the British Shipbuilding Research Association Technical Memorandum 500, May 1976, except where noted.

The following additional symbols were necessary for this report:

A_P	Projected area of planing surface, excluding external spary strips
B_{PX}	Maximum breadth overchines, excluding external spray strips
D_{BL}	Baseline draft at transom
D_{OA}	Overall draft at transom
D_T	Tunnel diameter
L_P	Projected length of chine

METRIC CONVERSIONS

1 degree (angle)	= 0.01745 rad (radians)
1 foot	= 0.3048 m (meters)
1 foot per second	= 0.3048 m/sec (meters per second)
1 inch	= 25.40 mm (millimeters)
1 knot	= 0.5144 m/s (meters per second)
1 fps	= 0.3048 m/s (meters per second)
1 lb (force)	= 4.448 N (Newtons)
1 in-lb (forces)	= 0.1130 N·m (Newton-meter)
1 long ton (2240)	= 1.016 metric tons, or 1016 kilograms
1 horsepower	= 0.746 kW (kilowatts)

ABSTRACT

This report consists of an experimental evaluation of tunnel hull configurations on a planing hull model and determination of the optimum longitudinal placement of the propeller in an existing tunnel design. Resistance, self-propulsion, and draft data are presented for Model 5048 fitted with twin tunnels which have a depth of 40 percent of the tunnel diameter. Effects of propeller tip clearance and nozzle sideplates installed in the tunnels were also investigated.

The longitudinal placement of the propeller inside the tunnel had a small effect on powering and draft with the forward location having slightly less delivered power than the aft locations. The addition of nozzle sideplates significantly reduced the draft, running trim and propulsive coefficient at high speeds. However, the nozzle sideplates significantly increased the resistance and delivered power.

ADMINISTRATIVE INFORMATION

The work described in this report was performed under the Surface Ship Hydromechanics Program, Task Area SF 43 400 001, Task 23556, Element 6254N. The work was sponsored by the Naval Sea Systems Command (03R) and funded under Work Unit 1507-101.

INTRODUCTION

A fundamental requirement for small, high performance craft intended for shallow water operation is that the craft should have minimum navigational draft. Conventional planing craft have propellers and appendages that project below the keel. Draft can be minimized through the use of small diameter propellers or waterjets. However, these techniques do not necessarily optimize propulsive efficiency.

Introduction, into the hull, of tunnels placed around the propellers offer many advantages to the designer in matching propulsive requirements to mission requirements. Advantages include: reduction in static draft due to the raising of the propellers relative to the baseline; increased propeller protection during beaching operations; and greaterr flexibility in placement of interior power plant and shafting. Results of experiments performed by Peck[1] indicated that the placement of propellers in tunnels has no adverse effects on propeller efficiency and, due to the shrouding effect of the tunnels, may increase the efficiency. However, the loss of planing surface and interior volume may produce a reduction in buoyancy and dynamic lift while underway.

Resistance and propulsion data on planing hulls equipped with tunnels is scare. References 2 and 3 presented results of experimentally determined effects of tunnel depth and propeller tip clearance on the propulsive efficiency of a planing hull model. In a report of limited distribution, the effects of adding nozzle sideplates or "wedges" which contract the tunnel exit area of a full-scale tunnel hull craft were investigated. Prior to the conduct of the experiments reported herein there was no information available on the effect of longitudinal propeller position on the powering performance of tunnel hull planing craft. This report contains the experimental results of a series of test performed at David W. Taylor Naval Ship Research and Development Center (DTNSRDC) for the purpose of determining the propulsive and trim characteristics of Model 5048 equipped with 40 percent tunnels, as a function of:

1. longitudinal placement of propellers in the tunnels; (3 locations)
2. propeller tip clearance inside the tunnels; (2 tip clearances) and
3. presence of nozzle sideplates inside each tunnel, to alter tunnel geometry.

MODEL DESCRIPTION

DTNSRDC Model 5048 was modified to accept twin tunnels within its original hull lines. The tunnels were designed by the Naval Ship Engineering Center,

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[1] References are listed on page 11.

Norfolk Division, Small Craft Engineering Department.

Model 5048 was selected as the parent hull form because it was representative of a hull which would be used with tunnel hull propulsion. (All references to the parent hull will mean the original hull without tunnels). The model has a constant deadrise over the entire afterbody. Model specifications are given in Table 1. The hull was modified to accept two fiberglass tunnels, details of which are shown in Figure 1. The tunnels were formed by intersecting sections of two 6.0 in (0.152 m) diameter cylinders, creating a roof angle forward of the propellers of 12 degrees, (see Figure 1C for definition of roof angle).

Appendages consisted of twin rudders (with stocks mounted directly behind the tunnel intersections with the transom), and propeller shafts and struts. When installed, the nozzle sideplates were located inside the tunnels at the transom and reduced the tunnel exit area.

The propeller rotation was outboard. Propeller diameters were 5.25 in (0.133 m) (propellers 4214 and 4215) and 6.0 in (0.152 m) (propellers 4175 and 4176), giving nominal tip clearance in the tunnels of 7.1 percent and 0.0 percent of the propeller diameters respectively. Mean values of open-water characteristics of the propellers are represented in Figure 2.

During testing, the model was ballasted to 341 lb (1.52 kN) and the center of gravity was located 40 percent L_P forward of the transom.

Instrumentation included linear potentiometers fore and aft to measure bow and stern vertical displacement data (for determining model attitude and trim), transmission dynamometers on each shaft to measure thrust and torque, six pressure gages located along the centerline of the port tunnel to measure tunnel roof pressure, a force gage to measure model towing force, and a geared shaft with magnetic pickup and instrumentation to measure shaft revolution rate. Pressure data were evaluated in a separate report[4] issued by the Naval Sea Systems Command, Detachment Norfolk.

TEST DESCRIPTION

The model was towed on the thrust axis using the DTNSRDC high-speed tow gear and was powered as close as possible to the model self-propulsion point throughout the propulsion tests. Resistance tests were conducted for each configuration of the appended hull with tunnels.

The self-propulsion tests planned consisted of tunnel hull model configurations with and without nozzle sideplates, with two propeller tip clearances (different propeller diameters), at each of three different propeller longitudinal placements corresponding to 25 percent, 50 percent, and 100 percent of the tunnel diameter (D_T) aft of the intersection (knuckle) of the horizontal and inclined portions of the tunnel roof. These locations will be referred to hereafter as the fore, mid, and aft locations respectively.

The accuracy of the 100 lb (444.8 N) capacity block gage used in these experiments for measuring resistance is $\pm$ 1/2 lb (2.224 N).

Vibration problems were encountered at high speeds with the large propellers. Consequently, these propellers were damaged and were not evaluated at the aft placement. Furthermore, due to insufficient space, the nozzle sideplates could not be placed in the tunnels with the propellers at the aft position. Model configurations and test conditions are summarized in the Appendix.

ANALYSIS AND PRESENTATION OF RESULTS

Tests were run at model speeds from 2 to 14 knots. However, below 5 knots the propeller Reynolds number was at or below 3.0×10^5, corresponding to a laminar or transitional flow regime[5]. Data were characteristically non-repeatable in this regime, and data spots that were in obvious error were omitted from the analysis.

The data was non-dimensionalized to be more useful to designers wishing to apply it to hulls of different dimensions. The data was corrected to salt water at 59° F using the Schoenherr friction formula and all propulsion data was adjusted to the model self-propulsion point. The Schoenherr friction formula was chosen to be consistant with past model experiments and with the Blount and Fox[6] prediction method which states that for a hard chine craft, a correlation allowance of zero produces best model-full scale correlation. Therefore all the experiments were conducted at C_A equal to zero.

Resistance and trim data for the appended tunnel hull with and without nozzle sideplates are presented in Figure 3. The change in resistance due to change in shaft and strut placement were found to be negligible.

Figures 4 through 13 present the propulsion data for the matrix of test conditions shown in the Appendix.

Trim and draft data from propulsion tests are given in Figures 4 through 6. Draft data refer to either draft at the baseline (keel in this case), D_{BL}, or overall draft, D_{OA}, which includes propeller projection below the keel (Figure 1B).

Figure 7 presents the ratio of delivered shaft horsepower, P_D, of the tunnel hull configurations to that of the parent hull configuration. Figures 8, 9, 10 and 11 present the thrust deduction factor, (1-t), thrust wake factor, $(1-w_T)$, torque wake factor, $(1-w_Q)$, and relative rotative efficiency (η_R), for the model selfproplusion condition. Propulsive efficiency, η_D, and shaft revolution rate, N, are presented in Figures 12 and 13.

DISCUSSION OF RESULTS

Changes in resistance for different shaft/strut positions in the tunnel were negligible. Above a $F_{n\nabla}$ of 1.75 the addition of nozzle sideplates increased the resistance. The increase in resistance with the addition of nozzle sideplates may be due partially to increased drag of the tunnel surface. Resistance changes may also develop due to trim changes which result from the altered (increased) pressure in the tunnel due to changes in the flow velocity in the tunnel.

The effect on powering of longitudinal propeller placement or tip clearance is minimal. The fore propeller location requires one to seven percent less power at $F_{n\nabla} = 3.0$, relative to the mid location. Above $F_{n\nabla} = 2.0$ the addition of nozzle sideplates increases the delivered power. The delivered power required of nozzle sideplate configuration was approximately 13 percent to 24 percent higher, at $F_{n\nabla} = 3.0$, than that of configurations without nozzle sideplates.

The greatest influence on running trim and draft is produced by the addition of nozzle sideplates. Nozzle sideplates tend to significantly decrease the running trim and, to a somewhat lesser degree, the running draft

Moving the propellers aft generally increases trim angle. For tests run without nozzle sideplates, the trim generally increases slightly with decreasing propeller tip clearance, with the maximum trim of approximately 6.0 degrees occuring at $F_{n\nabla} = 2.5$. Adding nozzle sideplates decreased trim greatly to a value between 2.0 and 2.5 degrees. Trim angles at self propulsion were slightly higher than those observed during the resistance tests at the same speeds.

The major reason for considering tunnel hull propulsion in a planning craft is the anticipated decrease in running draft over the running draft of a planning hull with a conventional propeller/appendage arrangement. Curves of baseline (keel) draft, $D_{BL}/\nabla^{1/3}$ (Figure 5), and overall draft, $D_{OA}/\nabla^{1/3}$ (Figure 6) as a function of volume Froude number, show identical trends, because as shown in Figure 1B, D_{BL} and D_{OA} differ by a constant for each hull configuration. The maximum draft occurred at the lowest speed reported ($F_{n\nabla} = 1.3$). The configuration with the mid propeller placements, 7.1 percent clearance and with nozzle sideplates had the least draft. The forward propeller location with 0 percent tip clearance and without nozzle sideplates had the greatest draft of all the configurations tested.

Nozzle sideplates produce a high pressure region aft of the propeller (reference [4]). This ram pressure, which provides additional lift locally, tends to decrease the trim angle and running draft. The magnitude of this lift force increases as the area of the tunnel wall aft of the propeller increases. The tests reported herein confirm this conclusion in that the running trim tends to decrease as the propeller is moved forward.

The propeller-hull interaction coefficients exhibit many of the same trends as shown in previous tests [2,3]. For example, (1-t) is relatively unaffected by propeller diameter; both $(1-w_Q)$ and $(1-w_T)$ are larger for the 7.1 percent tip clearance propellers; and η_R is highest for 0 percent tip clearance propellers. The following additional trends were observed. Thrust deduction factor, (1-t) presented in Figure 8, increased with $F_{n\nabla}$ for tests with nozzle sideplates. This is due to the significant increase in the resistance of the nozzle sideplate configurations relative to the without sideplate configuration as speed increases. In addition (1-t) is relatively unaffected by propeller placement or tip clearance when nozzle sideplates are not present. Configurations with nozzle sideplates exhibit a slightly greater variation in (1-t).

Denny[7] has derived a simplified mehtod to predict the portion of propeller induced pressure drag contributing to the tunnel hull thrust deduction for the various longitudinal propeller placements along with the total (1-t) found experimentally. The prediction is better for the 7.1 percent propeller tip clearance configuration than the 0 percent clearance configuration. It is noted that Denny calculates the mean velocities and induced pressure at the field points in the vicinity of the propeller and uses the Bernouilli theorem to calculate propeller induced pressure drag, which is then expressed as a thrust deduction. The experimentally derived thrust deduction includes the effect of shaft angle as well as thrust forces due to pressure on the hull. Therefore one would expect that the predicted (1-t) would be slightly higher then the measured (1-t) as shown in Figure 8.

A summary of the delivered power and overall draft relative to the delivered power and draft of the parent hull is shown in Table 2 for each of the configurations that were tested. It is clear that the configurations with the lowest overall draft have the highest delivered power, and conversely, the configurations with the best powering performance have the greatest draft.

CONCLUSIONS

Results from the experimental program with a tunnel hulled planing craft indicate that:

1. The longitudinal placement of the propeller in the tunnel has a small effect on the delivered power. In general, at a volume Froude number equal to 3.0, the forward propeller location resulted in a one to seven percent reduction in delivered power relative to the mid location.
2. In general, the tunnel hull configurations with the shallowest running draft had the highest required power. The shallowest running draft configuration with mid-propeller placement, nozzle sideplates and 7.1 percent propeller tip clearance

has a draft which was 67 percent of the parent hull running draft but required 150 percent of the parent hull delivered power.

The highest propulsive efficiency, 0.64 was achieved by the configuration with forward propeller placement, 0.0 percent tip clearance propellers and without nozzle sideplates. This configuration had the deepest running draft which was 85 percent that of the parent hull and had the least delivered power of all the tunnel hull configurations. The delivered power of this tunnel hull configuration was 121 percent of the parent hull delivered power.

3. In every case, addition of nozzle sideplates increased the resistance, delivered power and decreased the trim and draft. Power increases ranged from 13 to 24 percent and the draft reduction ranged from 11 to 16 percent.

REFERENCES

1. Peck, James G., "Tunnel Hull Cavitation and Propeller Induced Pressure Investigation," DTNSRDC Report SPD-597-01 (November 1974)

2. Ellis, Walter E. and Reuel Alder, "Propulsion Experiments with a Deep Tunnel Planing Hull," DTNSRDC Report SPD-717-01 (February 1977)

3. Harbaugh, K.H. and D.L. Blount, "An Experimental Study of a High Performance Tunnel Craft," presented at the Spring meeting of the Society of Naval Architects and Marine Engineers, Lake Buena Vista, Florida (April 1973)

4. Denny, Stephen B., "Tunnel Hull Planing Craft: Propeller Induced Mean Tunnel Forces," NAVSEADET Norfolk Report 6660-66 (October 1980)

5. Comstock, John P. Editor, "Principals of Naval Architecture," published by SNAME, Revised edition, (1976)

6. Blount, D.L. and D.L. Fox, "Small Craft Power Predictions," Western Gulf Section, Society of Naval Architects Marine Engineers, (February 1975)

7. Denny, Stephen B., "Tunnel Hull Planing Craft: Prediction of Propeller Induced Tunnel Hull Resistance," NAVSEADET Norfolk Report 6660-59 (September 1980)

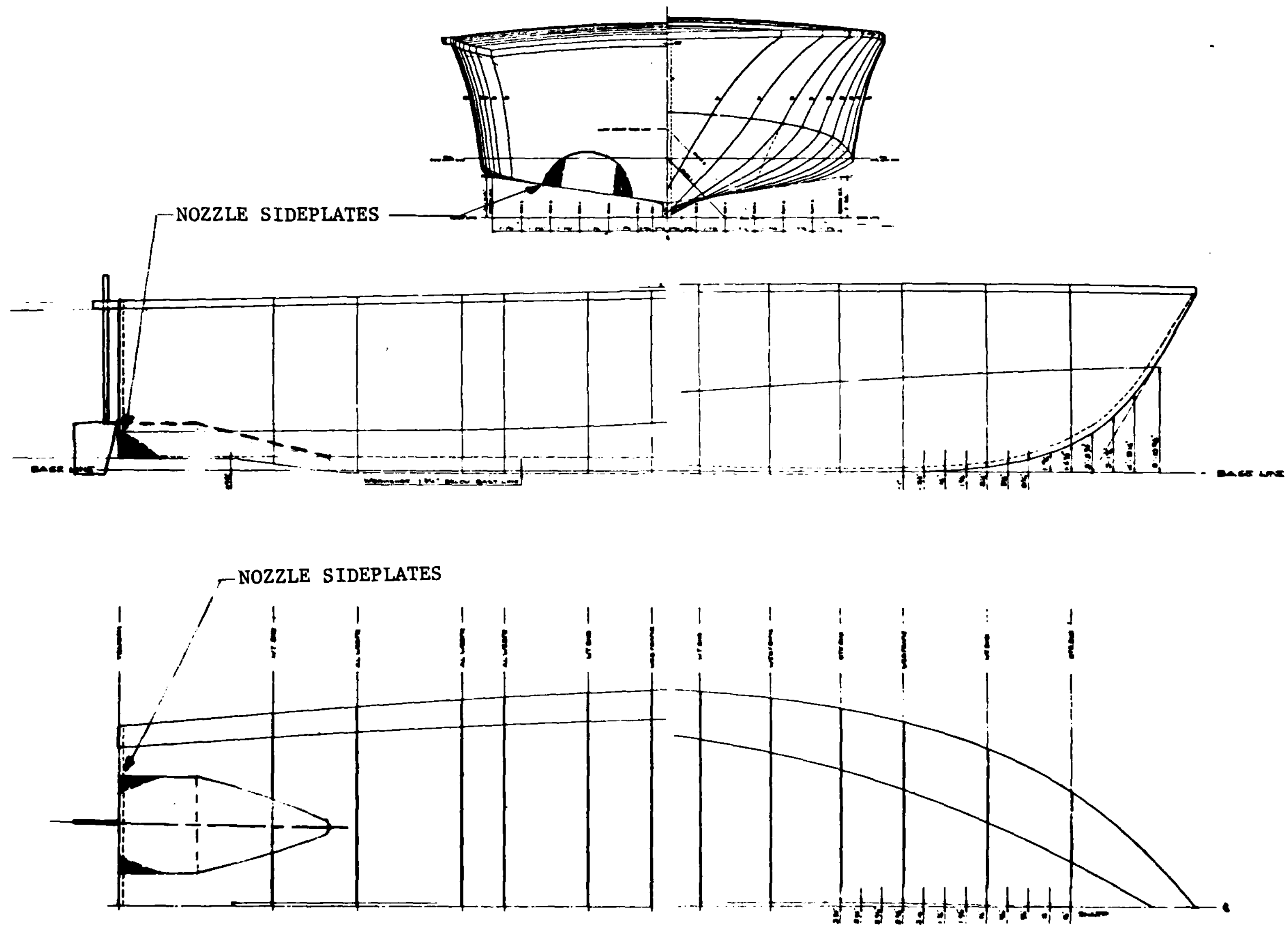

Figure 1A - Model 5048 with 40% Tunnels and Nozzle Sideplates Installed

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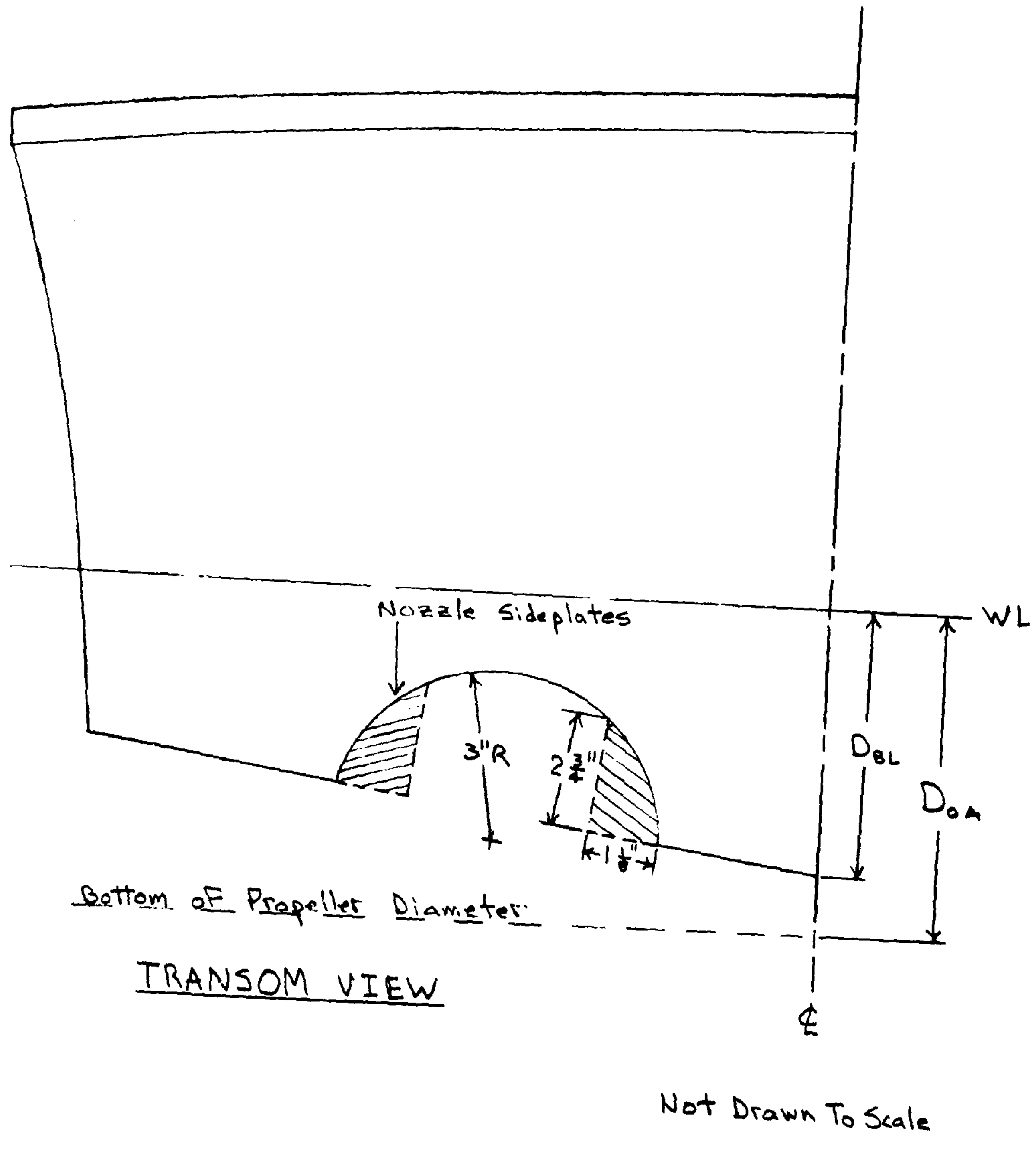

Figure 1B - Details of Tunnels, Nozzle Sideplates, and Draft Reference Lines

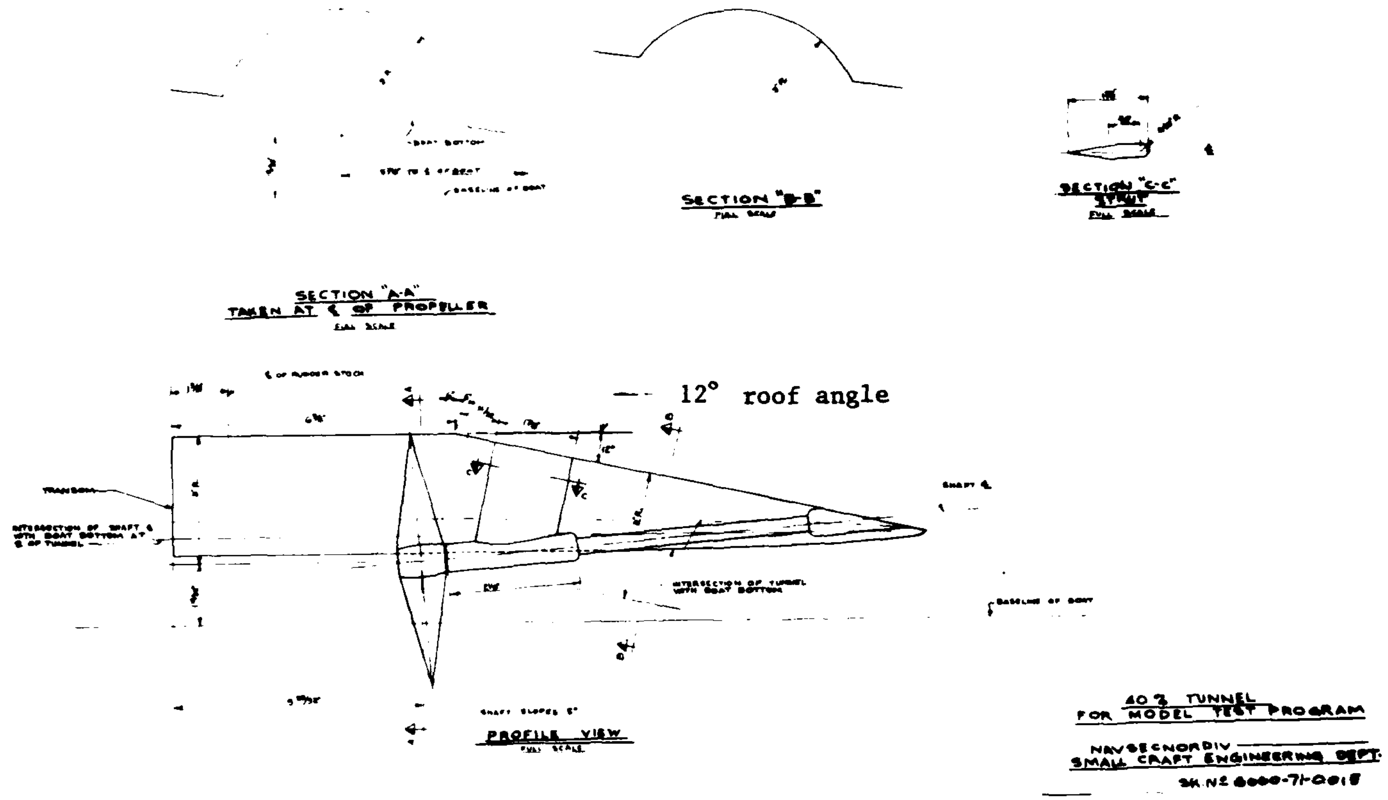

Figure 1C - Details of Tunnel Design

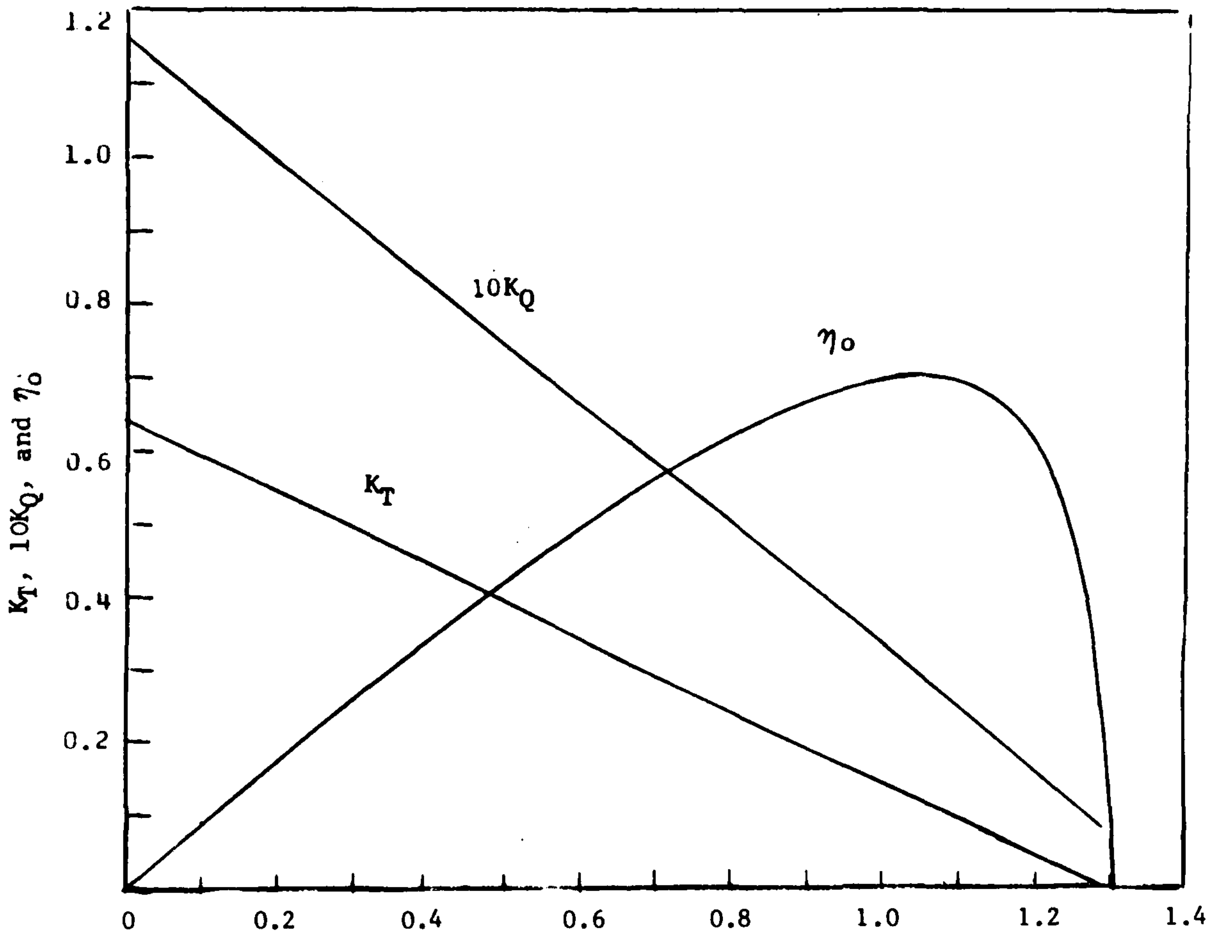

Figure 2A - Open Water Performance Characteristics for the 6.0 in (0.152 m) Diameter (0.0% Tip Clearance) Propellers 4175 and 4176

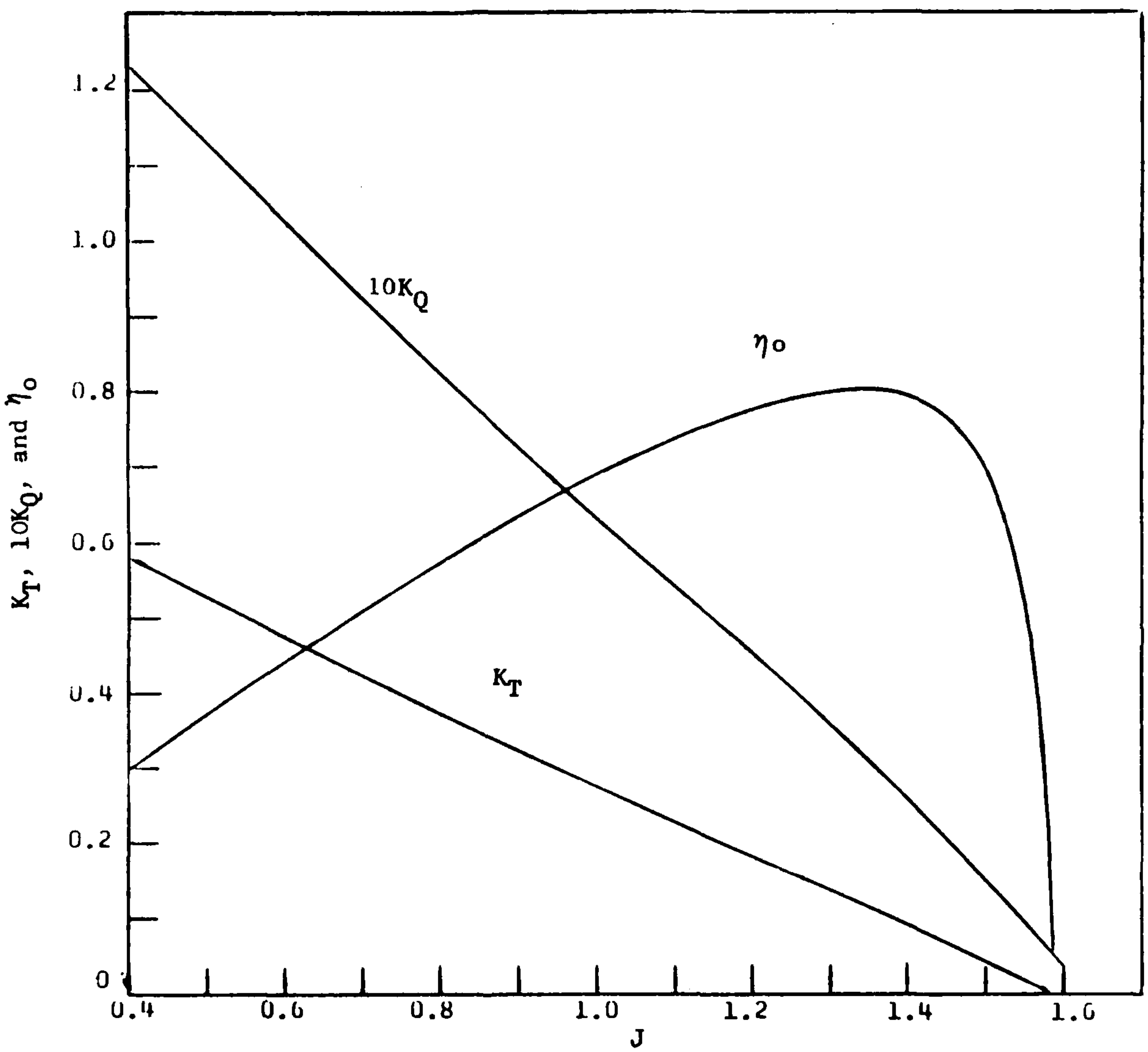

Figure 2B - Open Water Performance Characteristics for the 5.25 in (0.133 m) Diameter (7.1% Tip Clearance) Propellers 4214 and 4215

Parent hull had 5.875 in (15.0 cm) propellers

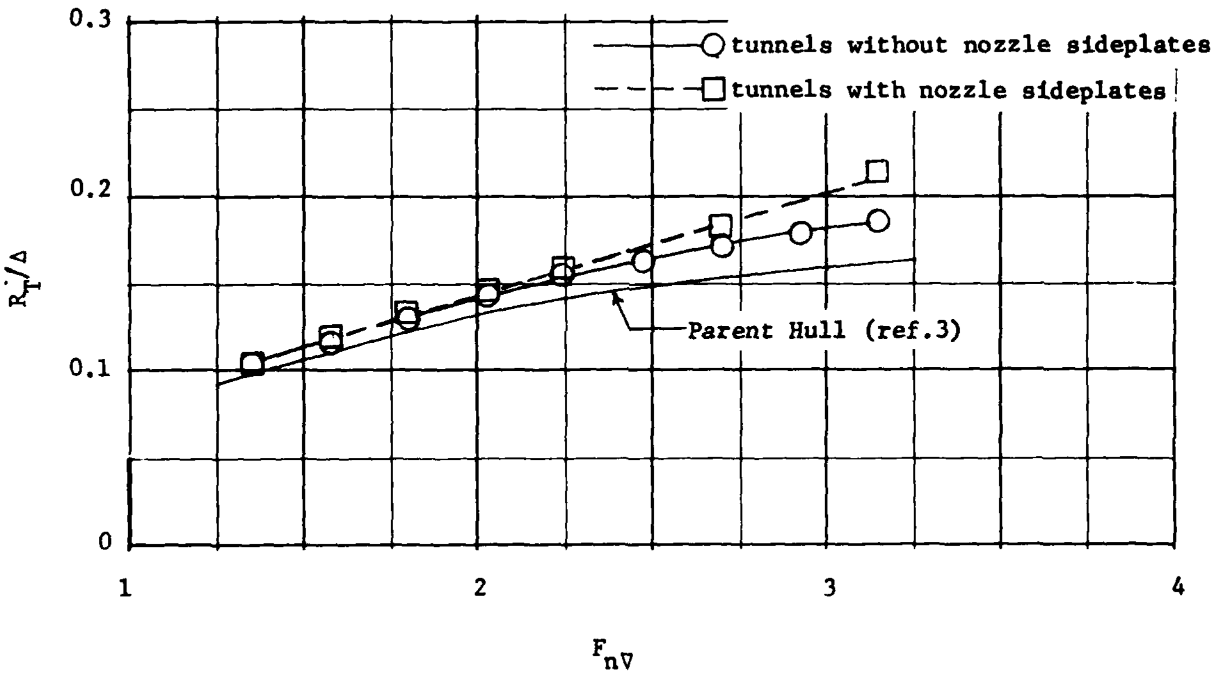

Figure 3A - Resistance Coefficient for the Appended Tunnel Hull

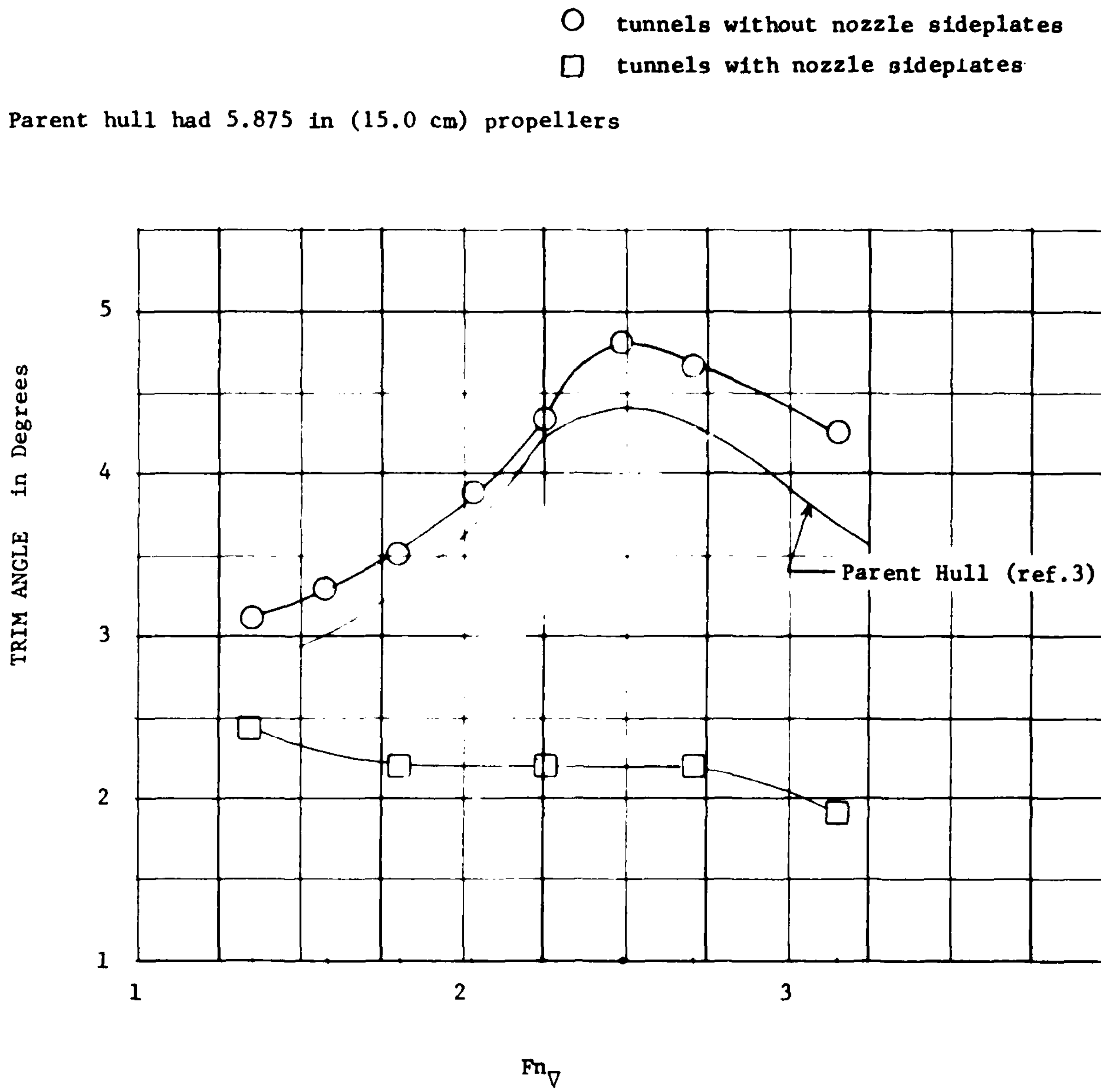

Figure 3B - Trim Angles from Resistance (P_E) Tests on the Appended Tunnel Hull

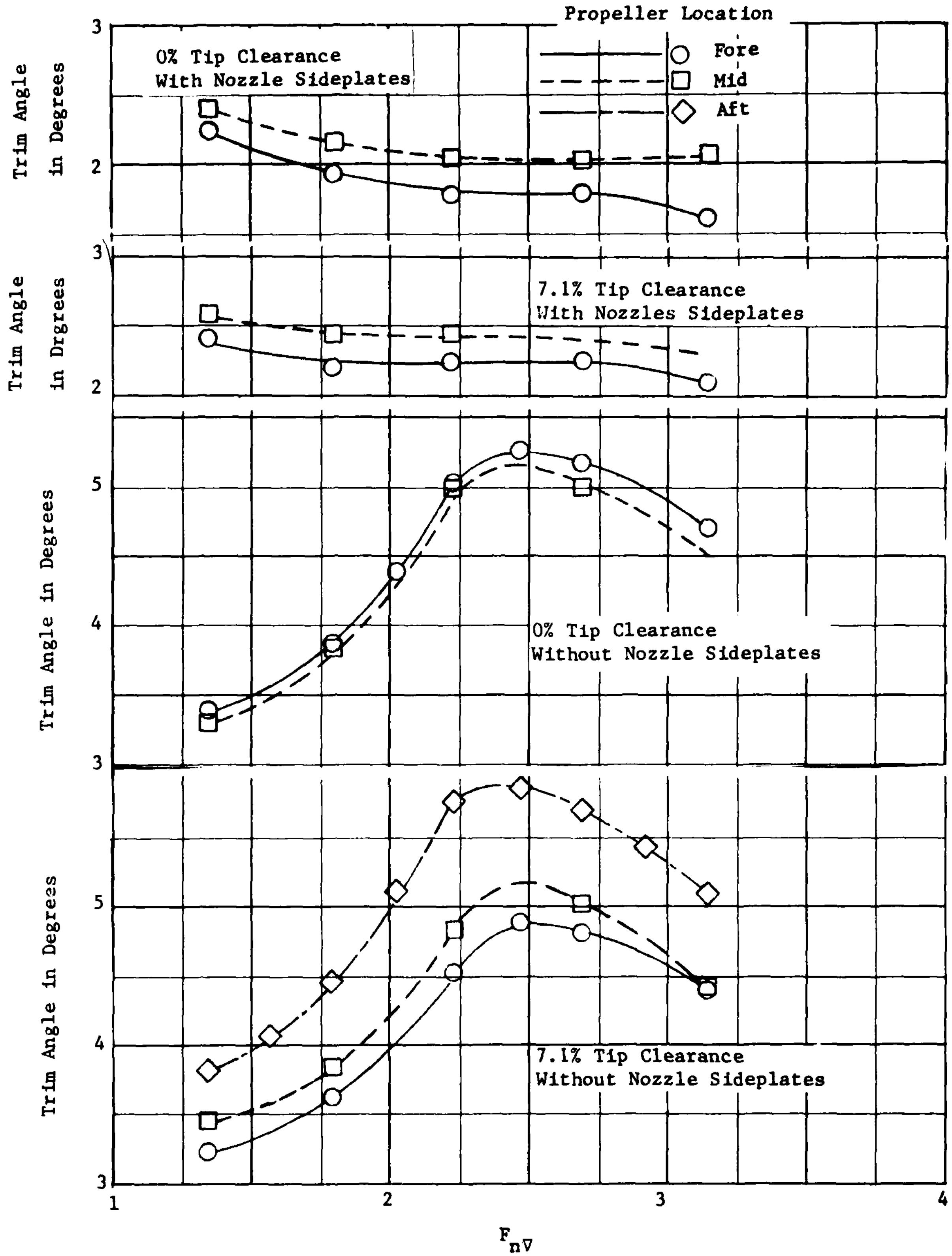

Figure 4 - Trim Angle From Propulsion (P_D) Tests as a Function of Froude Number for Various Positions of the Propellers

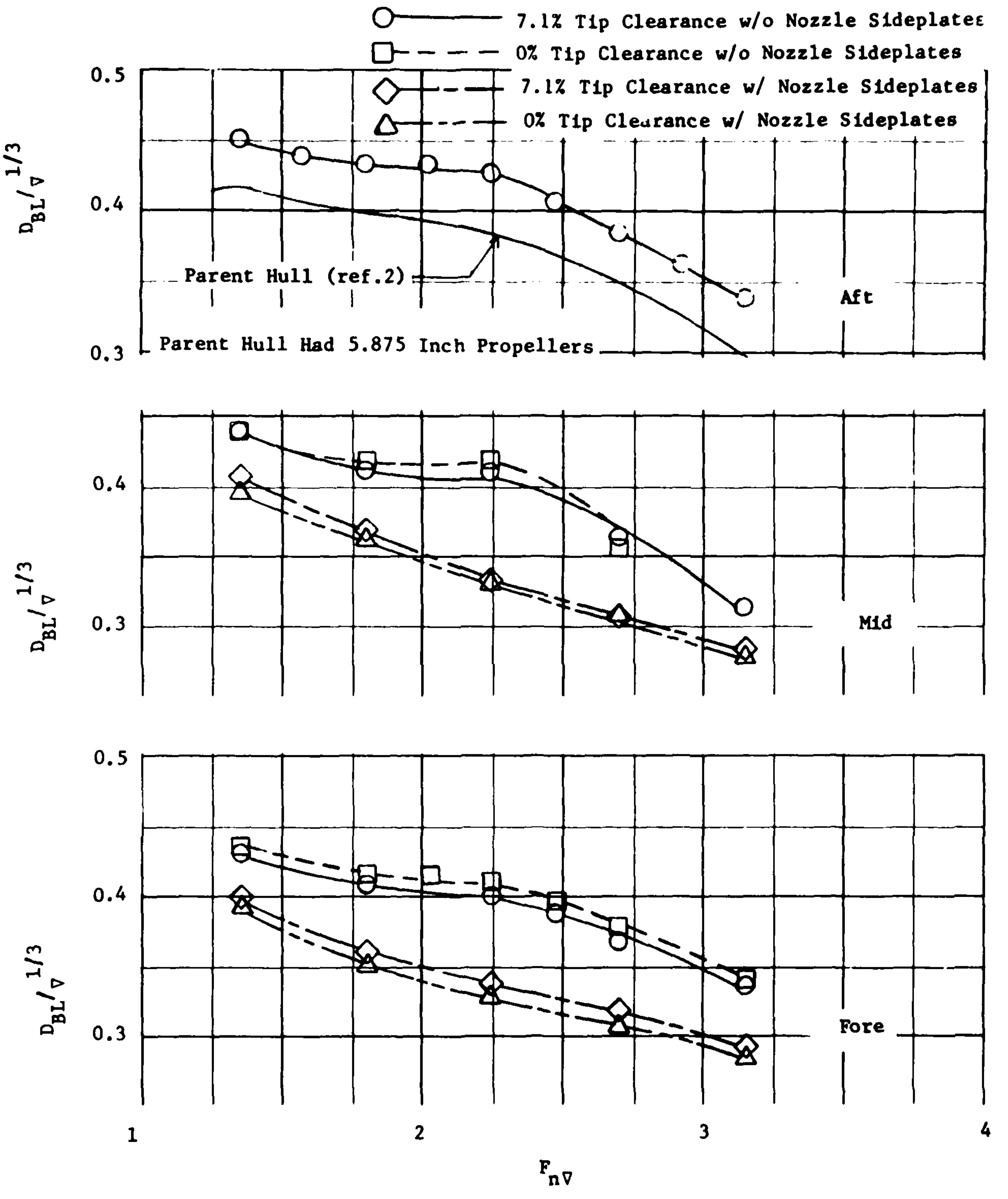

Figure 5 - Baseline Draft as a Function of Froude Number for Various Tip Clearances and Nozzle Geometries

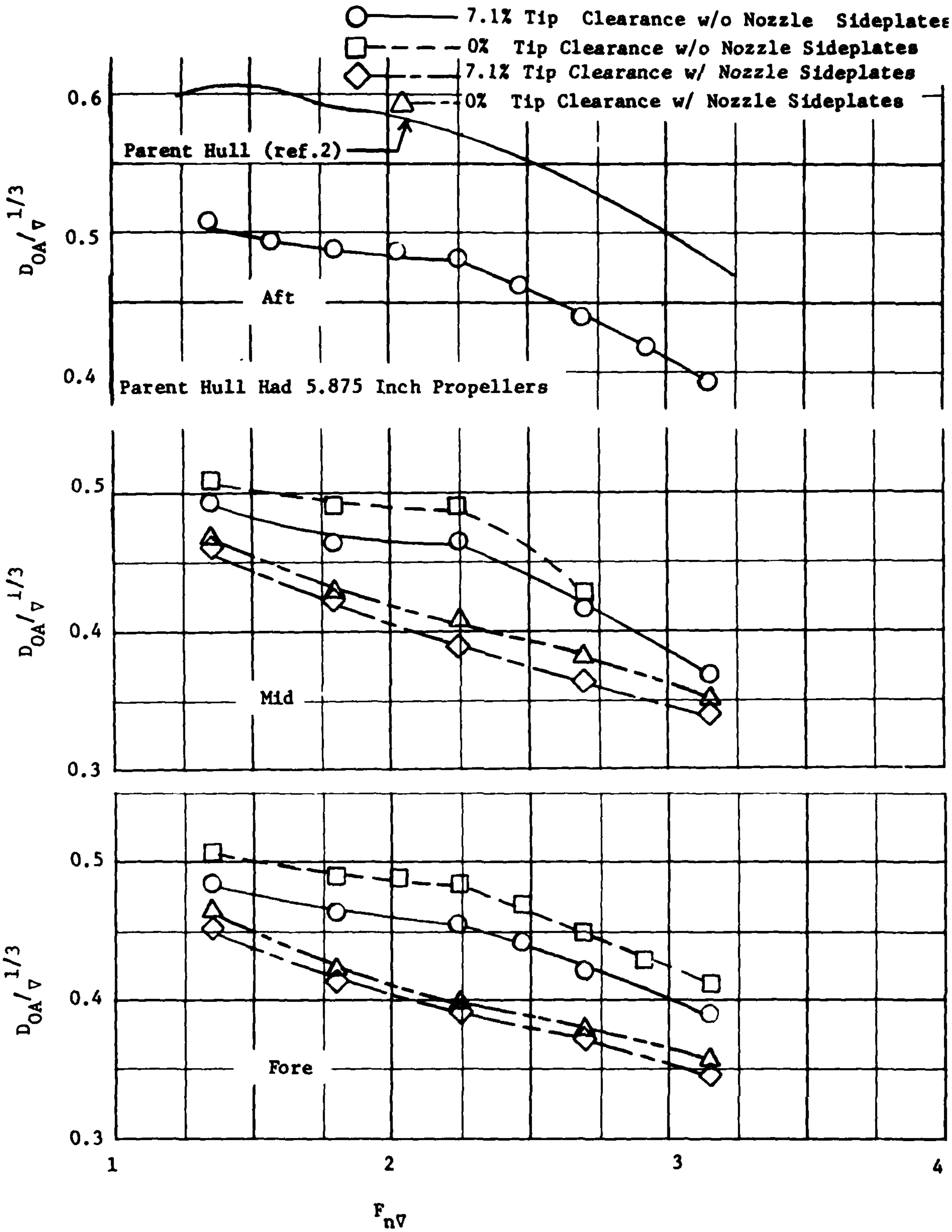

Figure 6 - Overall Draft as a Function Froude Number for Various Tip Clearances and Nozzle Geometries

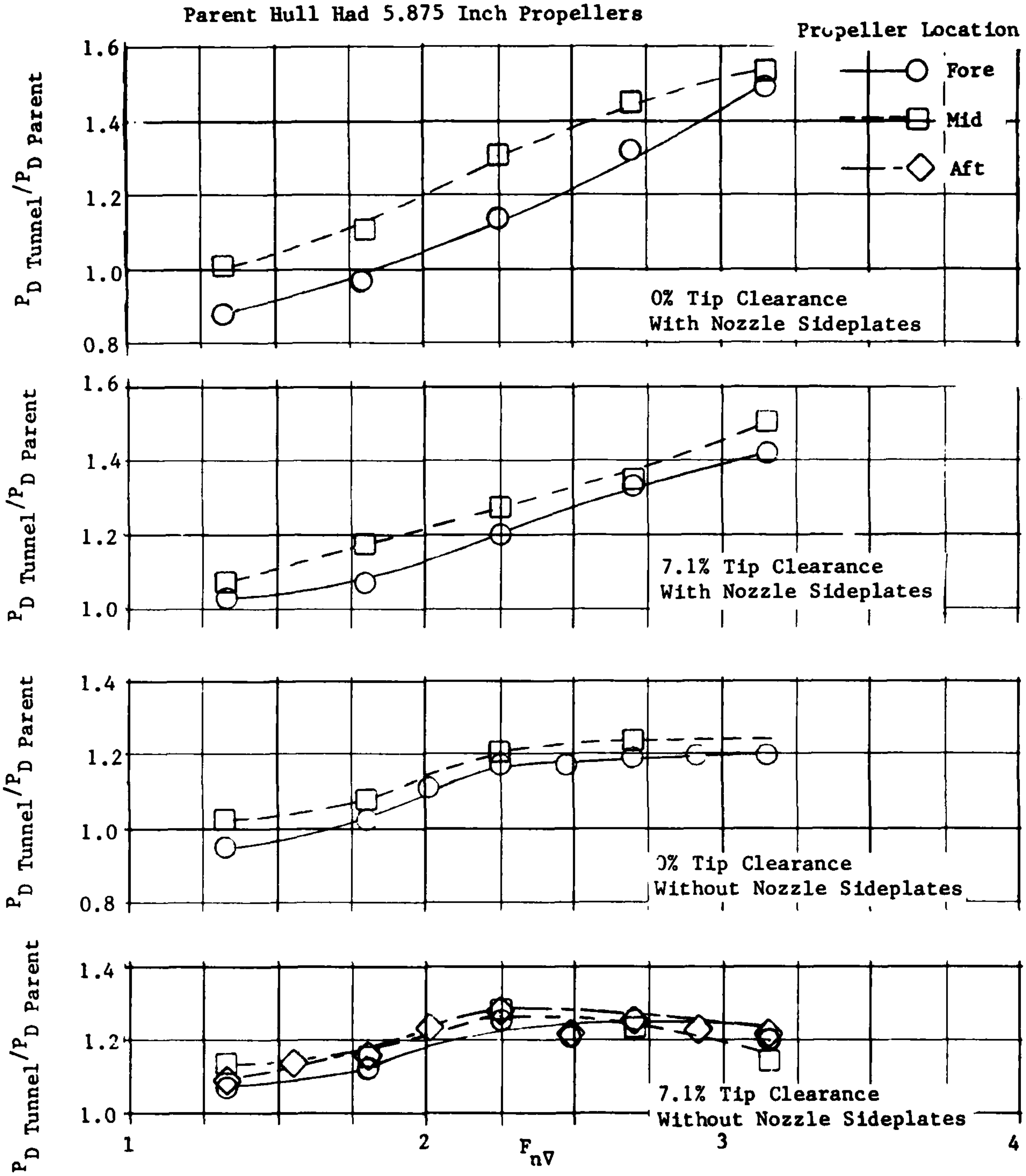

Figure 7 - Normalized Power Ratio, $P_{D\ Tunnel}/P_{D\ Parent}$, as a Function of Froude Number for Various Positions of the Propellers

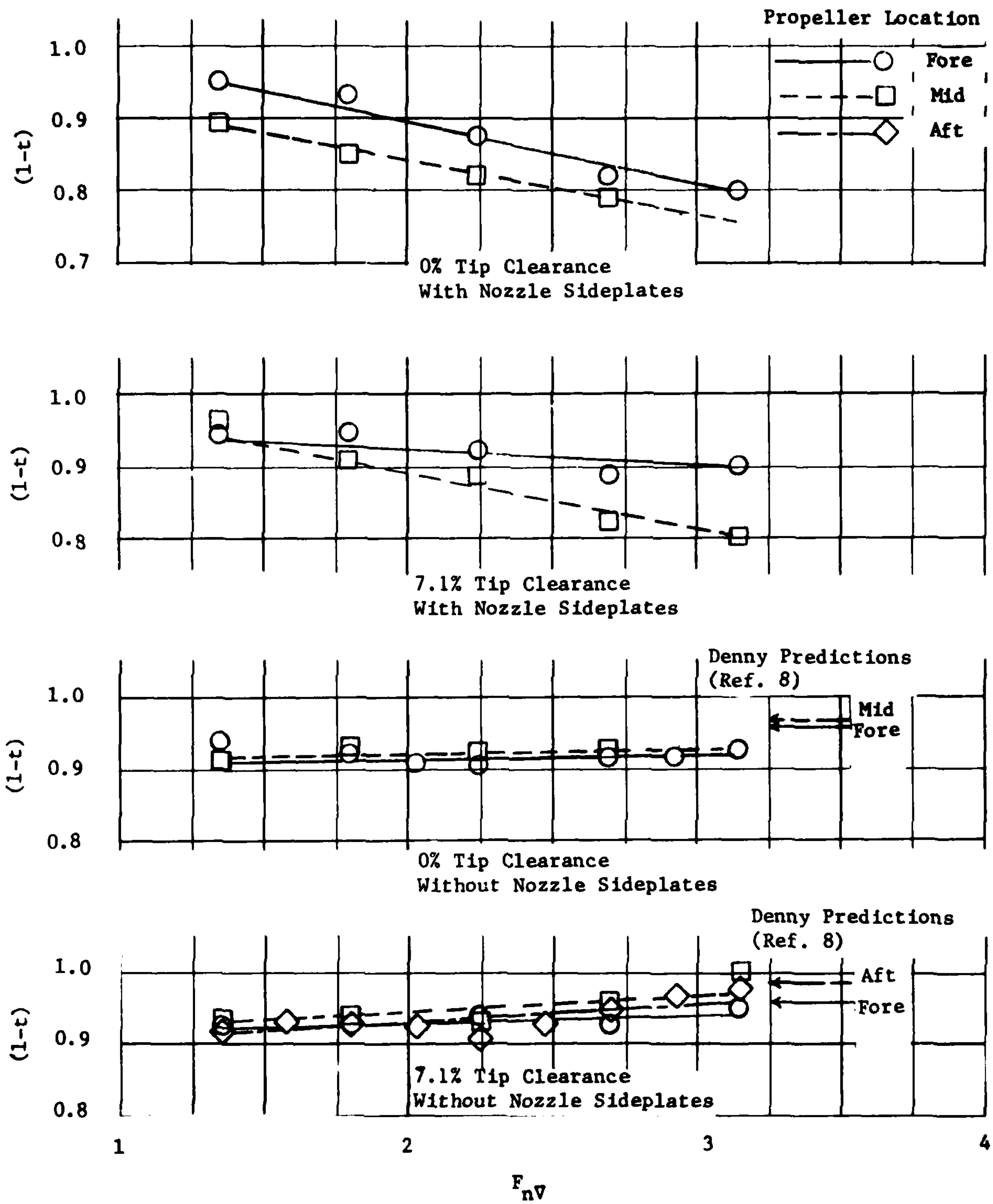

Figure 8 - Thrust Deduction of a Function of Froude Number for Various Positions of the Propellers

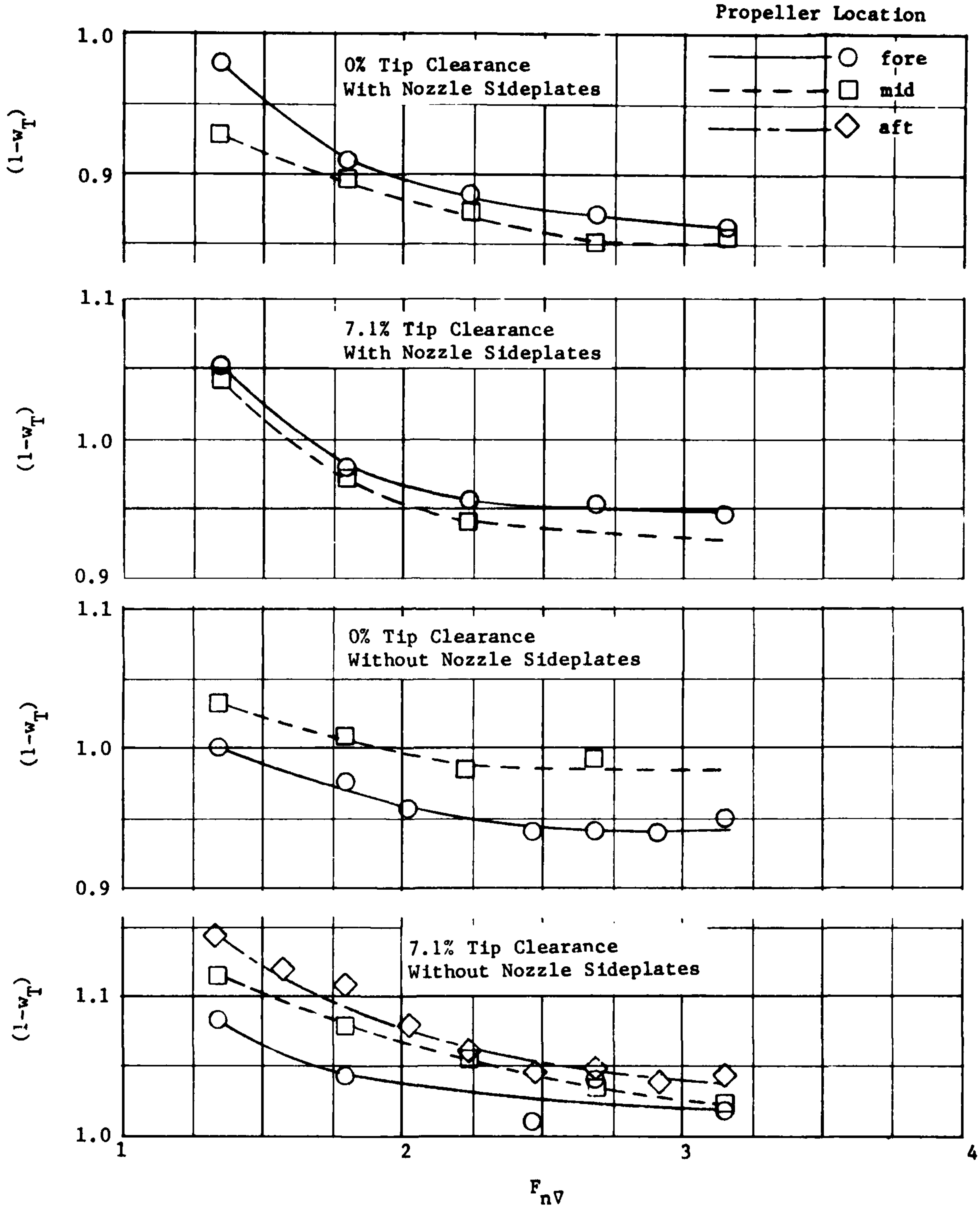

Figure 9 - Wake Factor Based on Thrust as a Function of Froude Number for Various Positions of the Propellers

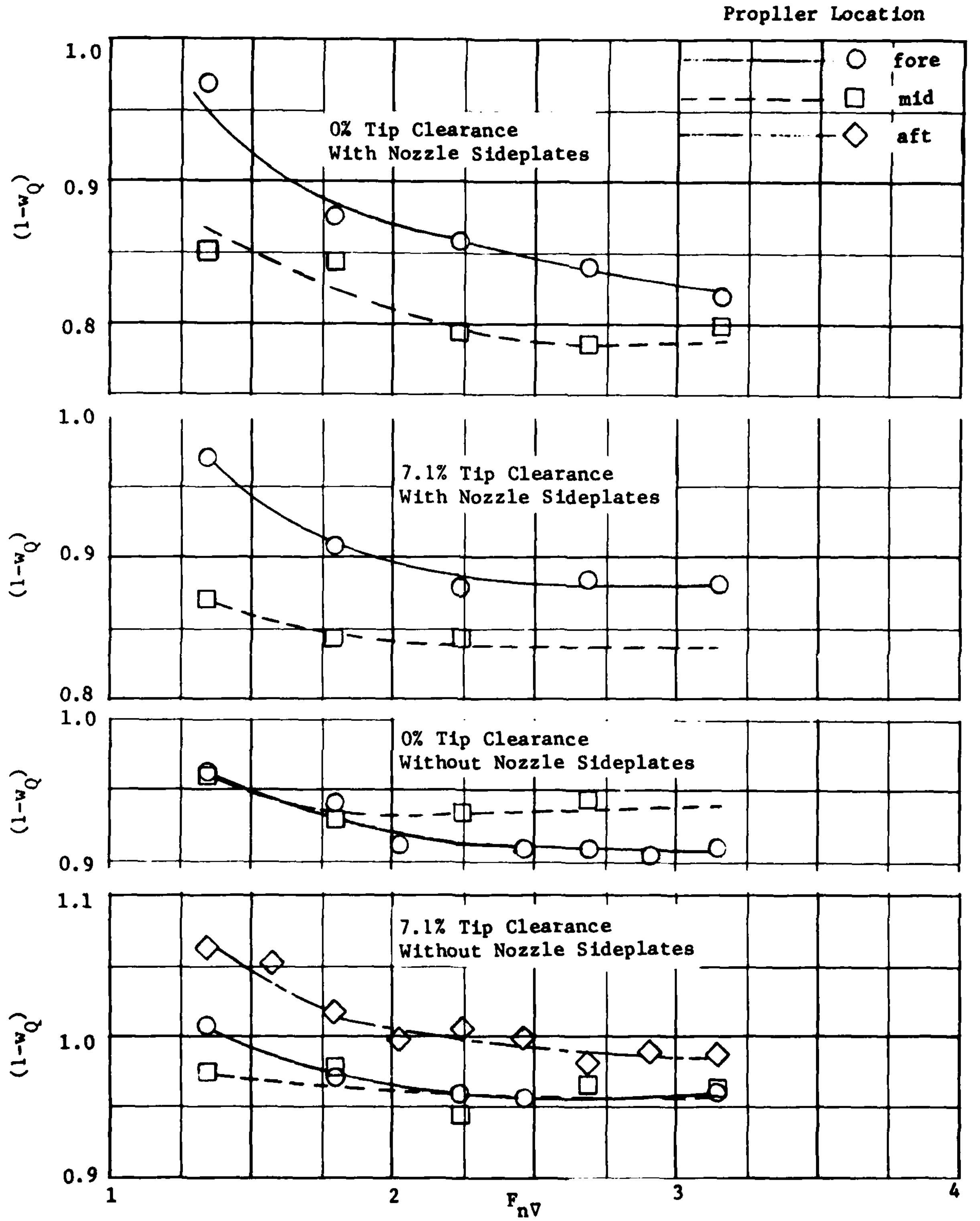

Figure 10 - Wake Factor Based on Torque as a Function of Froude Number for Various Positions of the Propellers

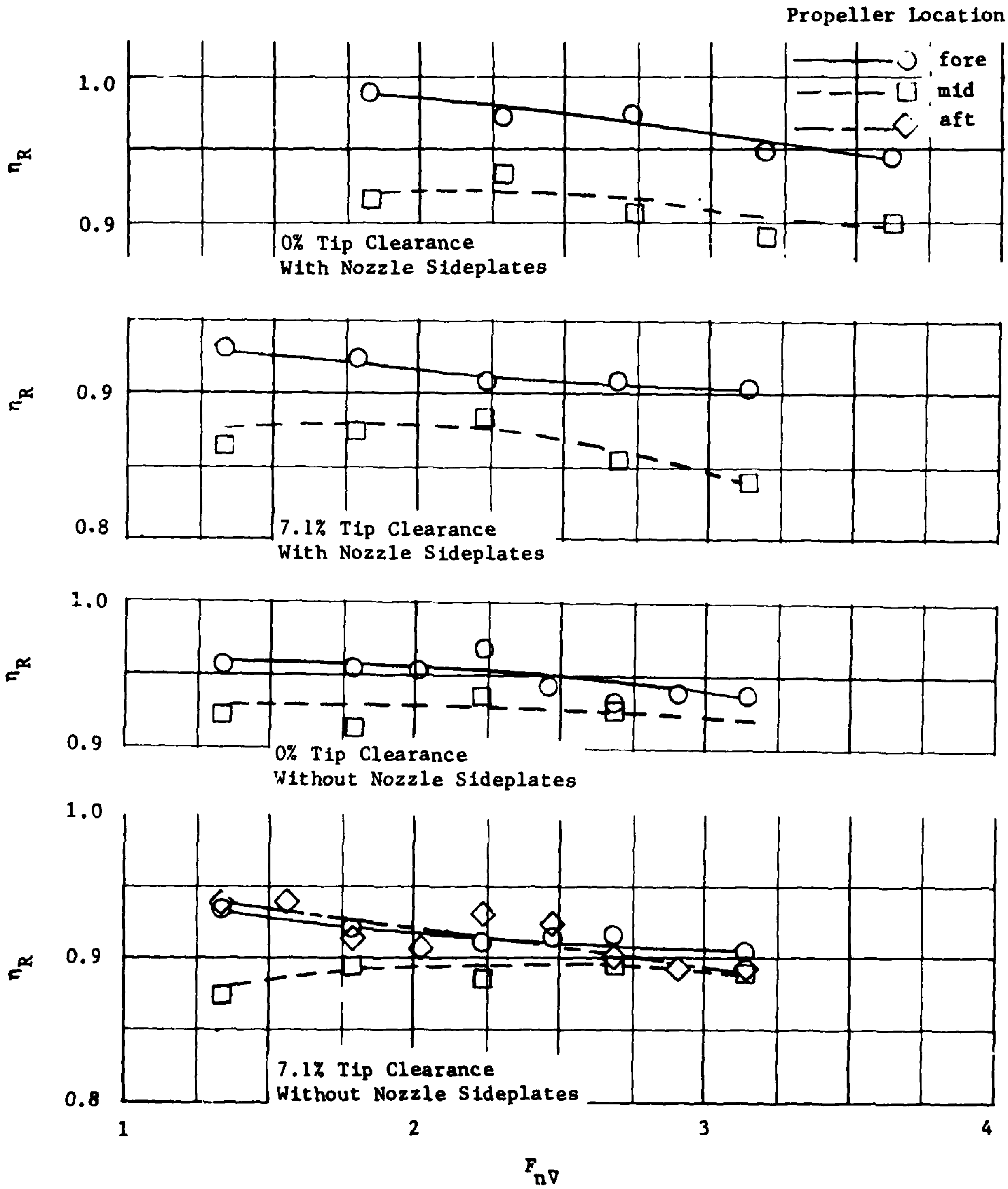

Figure 11 - Relative Rotative Efficiency as a Function of Froude Number for Various Positions of the Propellers

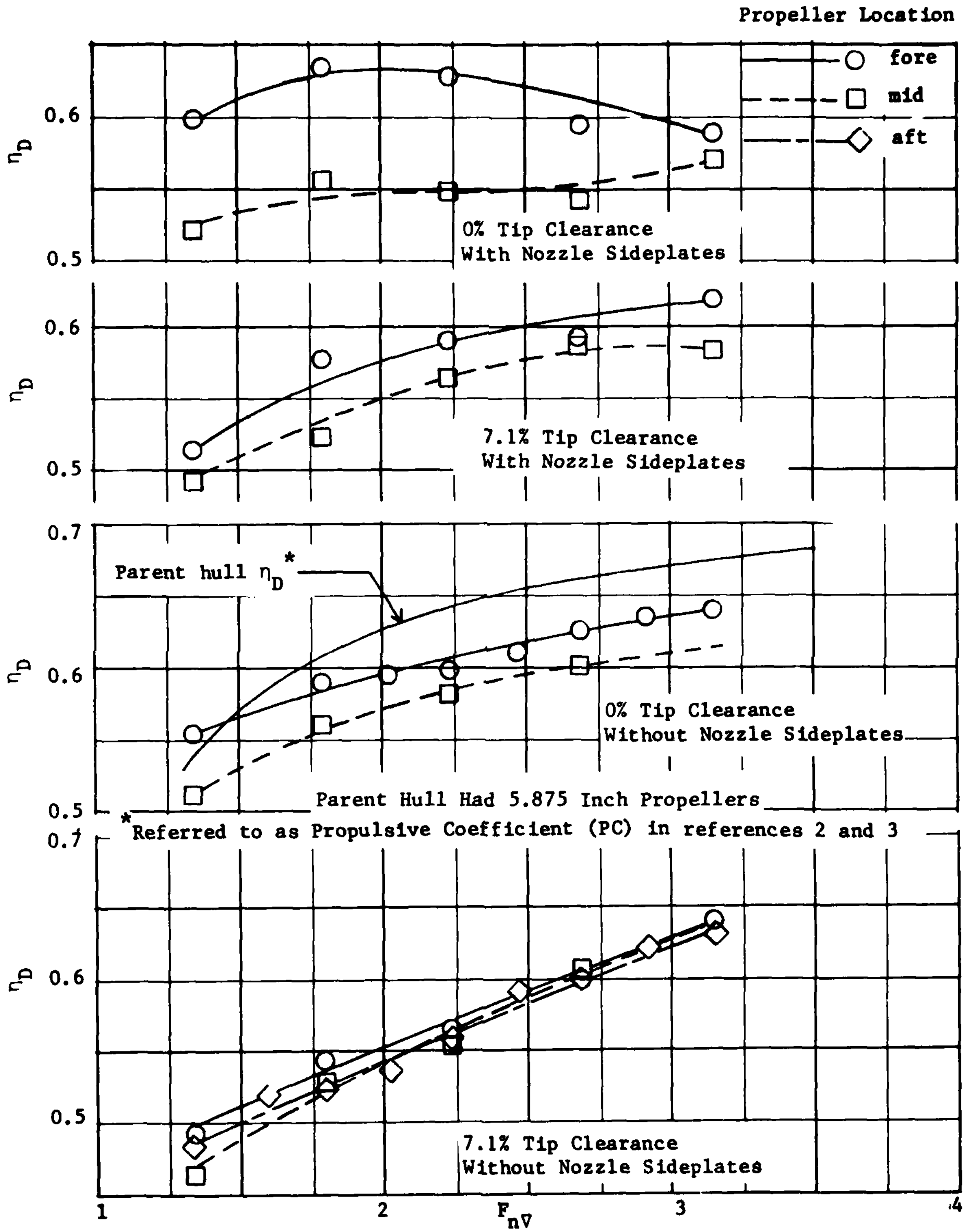

Figure 12 - Overall Propulsive Efficiency as a Function of Froude Number for Various Positions of the Propellers

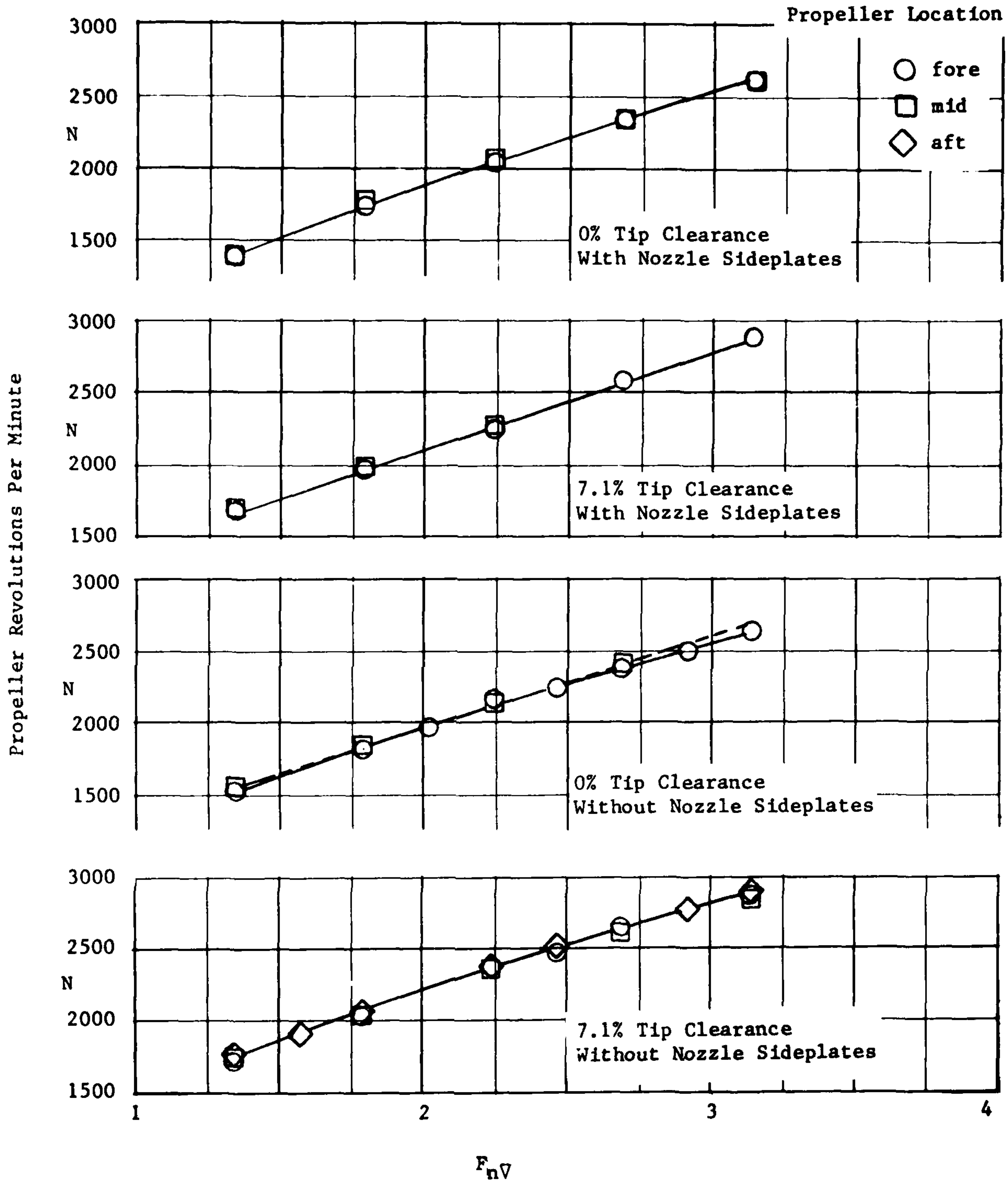

Figure 13 - Propeller Revolution Rate (RPM) as a Function of Froude Number for Various Positions of the Propellers

TABLE 1 - SPECIFICATIONS OF MODEL 5408

L_{OA}	10.125 ft (3.086 m)
L_P	9.75 ft (2.972 m)
B_{PX}	2.62 ft (0.798 m)
A_P	20.65 ft^2 (1.918 m^2)
Projected Area per rudder	0.078 ft^2 (0.00725 m^2)
Deadrise at Transom	8.5°
Shaft Angle (with respect to baseline)	
hull w/o tunnels	12°
hull w/ tunnels	5°

TABLE 2 - THE EFFECT OF PROPELLER PLACEMENT, NOZZLE CONFIGURATION AND PROPELLER TIP CLEARANCE ON THE DRAFT AND POWERING PERFORMANCE OF MODEL 5048 EQUIPPED WITH TWIN TUNNEL HULL PROPULSION

TUNNEL HULL CONFIGURATION	PROPELLER EFFICIENCY	$\frac{\eta_D \text{ TUNNEL}}{\eta_D \text{ PARENT*}}$	$\frac{P_D \text{ TUNNEL}}{P_D \text{ PARENT}}$	$\frac{D_{OA} \text{ TUNNEL}}{D_{OA} \text{ PARENT}}$
Forward Propeller Percent				
With nozzle sideplates 0 percent clearance**	0.60	0.89	1.50	0.73
With nozzle sideplates 7.1 percent clearance	0.62	0.92	1.40	0.71
Without nozzle sideplates 0 percent clearance	0.64	0.95	1.21	0.85
Without nozzle sideplates 7.1 percent clearance	0.63	0.94	1.23	0.80
Mid Propeller Placement				
With nozzle sideplates 0 percent clearance	0.57	0.84	1.53	0.72
With nozzle sideplates 7.1 percent clearance	0.59	0.87	1.50	0.69
Without nozzle sideplates 0 percent clearance	0.62	0.92	1.24	--
Without nozzle sideplates 7.1 percent clearance	0.63	0.93	1.24	0.77
Aft Propeller Placement				
Without nozzle sideplates 7.1 percent clearance	0.62	0.92	1.24	0.83

* The parent hull is model 5048 with conventional shafts and struts twin-screw propulsion arrangement.

** Percent clearance refers to distance from propeller tip to tunnel wall expressed as a percentage of propeller diameter.

APPENDIX: TEST MATRIX FOR RESISTANCE AND PROPULSION TESTS ON MODEL 5048

Resistance (P_E) tests were conducted with and without nozzle sideplates for each tunnel configuration.

PROPULSION (P_D) TEST MATRIX

PROPELLER PLACEMENT	TIP CLEARANCE	NOZZLE SIDEPLATES CONFIGURATION
FORE	0.0 %	With
	7.1 %	With
	0.0 %	Without
	7.1 %	Without
MID	0.0 %	With
	7.1 %	With
	0.0 %	Without
	7.1 %	Without
AFT	7.1 %	Without

All tests conducted with the model ballasted to a total displacement of 341 pounds (1516.8 newtons) and the center of gravity 40 percent of LP forward of the transom.

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

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